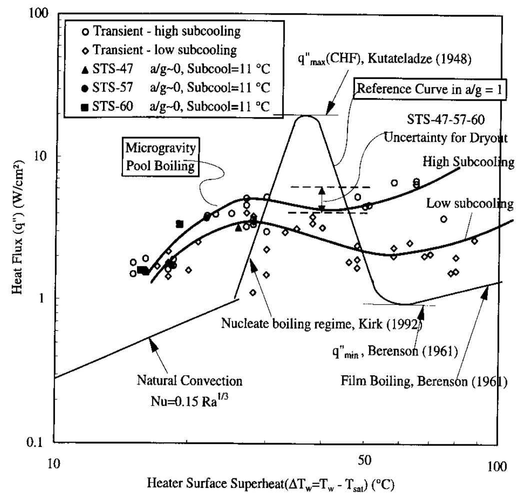
Case Studies: GRC's Recent Contributions to Use of Boiling in Spacecraft Thermal Systems

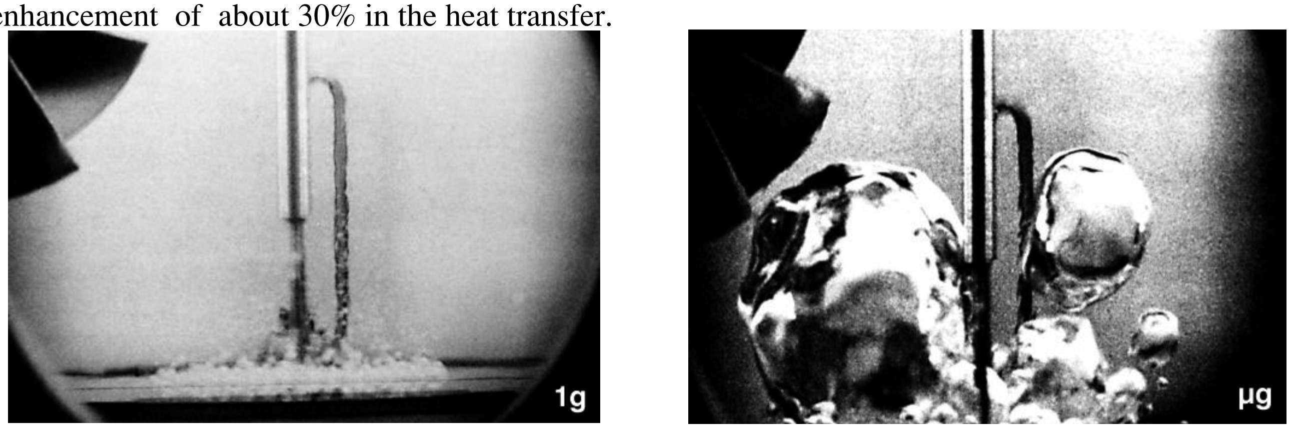
Boiling and condensation systems are widely used on earth due to increased heat transfer rates and reduced mass and volume, when compared to single-phase heat transfer systems. Reluctance to use these systems in spacecraft originates with uncertainty about their performance in microgravity. Historically, answers were unavailable for such simple performance requirements as whether steady state boiling was achievable, whether or not dryout would occur causing a destructively high temperature at the heater surface, and whether stable operation was achievable over a sufficiently wide range of conditions.

GRC, with the University of Michigan, conducted a series of pool boiling experiments on the Shuttle. A flat plate heater consisting of a thin gold film deposited on quartz substrate was used with R-113 as a fluid. To study the boiling characteristics, a matrix of photographs was analyzed with measured mean heater surface temperatures and derived heat transfer coefficients. Most importantly, steady-state pool boiling was achieved, and is attributed to a new vapor bubble removal mechanism. A peculiar phenomenon was discovered, defined as vapor bubble migration, where numerous tiny bubbles nucleate and then move toward a large bubble attached to the heater, providing an enhancement of about 30% in the heat transfer.

A boiling curve was constructed using steady state boiling data, and indicates an enhancement over 1g in the nucleate boiling regime, which increases with subcooling. The Critical Heat Flux, however, was shown to be significantly decreased in microgravity. This information is directly applicable for the inclusion of the boiling process in spacecraft thermal management systems.



Comparisons of pool boiling curves for R-113 in earth gravity and micro-gravity. Microgravity data are steady and quasi-steady measurements from three space shuttle missions.



Pool boiling in normal gravity (left) and microgravity (right)